EFFECT OF RATE OF ETHEPHON AND CARRIER ON INFLORESCENCE INITIATION IN 'SMOOTH CAYENNE' PINEAPPLE (*ANANAS COMOSUS* (L.) MERR.)

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I. INTRODUCTION

Pineapple (Ananas comosus (L.) Merr.) is the only member of the family Bromeliaceae which is cultivated as a food crop. It is also the only food crop in which inflorescence development can be initiated by application of a growth regulator.

Climate, physiological and cultural factors affect natural inflorescence initiation such that a variable percentage (often much less than 100%) of the plants in a field normally flower under optimum conditions for natural flower initiation, even after 15 to 18 months of growth (Dass et al., 1970; W.G. Sanford, personal communication). Climate, plant size, variety, and fertilization practices also have been reported to influence susceptibility of pineapple to forcing agents (Collins, 1960; Teisson, 1972). Despite some variations in plant response to forcing agent, artificial floral induction results in more uniform fruiting and increased yield because it increases the percentage of fruits which can be harvested (Evans, 1959; Aubert, 1977). A large number of compounds have been used to induce flowering in pineapple but they were not equally effective (Clark and Kerns, 1942; Gowing and Leeper, 1961a, 1961b, 1961c).

The chemicals that are presently in commercial use include the sodium salt of α-naphthalene acetic acid (SNAA), calcium carbide from which acetylene is generated upon hydrolysis, ethylene, and ethephon (2-chloroethyl phosphonic acid) (Gowing and Leeper, 1955; Py and Guyot, 1970; Wee and Ng., 1971). In many parts of the world, calcium carbide and NAA are used to induce flowering in pineapple while in Hawaii, ethephon and ethylene are commonly used (Aubert, 1973).

Basic research has indicated that the efficacy of ethephon as a forcing agent varies with the quantity applied and the pH of the ethephon solution (Dass et al., 1975). Urea is generally used as an adjuvent at concentrations ranging from 2% in India (Dass et al., 1975) to 4% in Hawaii. It is also possible that the concentration of ethephon at a given rate affects inflorescence initiation and/or fruit development (Guyot and Py, 1970b; A. Hepton, personal communication).

No systematic study of the effect of concentration and quantity of ethephon has been conducted in Hawaii in order to increase the precision with which ethephon is used as a forcing agent. If efficacy can be maintained or enhanced by reducing the rate or changing the concentration of chemical applied, a number of benefits will occur. These include:

1. Decreasing the cost per acre for ethephon application by decreasing the amount of ethephon used or decreasing the amount of water hauled to the field.

2. A sharpening of the harvest peak, thus decreasing the number of harvest rounds.

3. Increasing the percentage of recoverable fruits per unit of land area.

The objectives of this research were to:

1. Determine the minimum quantity of ethephon required to induce inflorescence development (flowering) in pineapple.

2. Examine the effect of different rates and concentrations of ethephon on the induction and rate of inflorescence development.

3. Examine the effect of ethephon rates and concentrations on fruit weight, shape, quality, and on the average number of slips and suckers produced per plant.

II. REVIEW OF LITERATURE

Natural Differentiation

Vegetative growth and reproductive development of pineapple (Ananas comosus(L.) Merr.) is usually affected by variation in the climate throughout the year (van Overbeek and Cruzado, 1946 and 1948; Teisson, 1972). In an experiment conducted with the cultivar Red Spanish, van Overbeek and Cruzado (1946) found that small (immature) and large (mature) plants flowered naturally in response to the cooler temperature of the winter months. Later, it was found that low temperatures were more effective in promoting floral initiation of the Red Spanish cultivar than reduced daylength (van Overbeek and Cruzado, 1948). However, in Hawaii, flowering of 'Smooth Cayenne' was not strictly a response to photoperiod or to low temperature, but also could take place during any period of the year, depending on the planting date and the type of planting material used (Gowing, 1961).

Like many other physiological processes, flower induction in pineapple is determined by the genotype and possibly its interaction with environmental factors such as temperature and daylength (van Overbeek and Cruzado, 1946 and 1948). The genotype effect was evident in an experiment carried out in Puerto Rico where van Overbeek and Cruzado noticed a significant difference in flowering percentage between Red Spanish and Cabezona varieties grown under similar conditions.

The length of the pineapple crop cycle, from planting to harvest of a marketable fruit is determined by the type of planting material, but primarily by its weight (Py and Tisseau, 1965; Py et al., 1968). This is because plants grown from large planting pieces reach the minimum size required for flower initiation more quickly than those grown from small pieces.

Flower induction of Smooth Cayenne occurs throughout the year at the equator due to the lack of prominent seasonal changes, with time of flowering being a function of plant size (Aubert, 1977). Lacoeuilhe and Guyot (1979) also stated that the large shoots which develop from the base of the mother plant (suckers) differentiate earlier than small ones. They also stated that meteorological factors, and particularly a short daylength and low insolation, are associated with inflorescence initiation in pineapple. In the Ivory Coast (about 5°N latitude) where the change in daylength is very small, with little or no change in night temperature, the stimulus to flower once the plant has reached sufficient size is thought to be associated with the reduction in hours of sunshine (Teisson, 1972).

In Hawaii, natural flower initiation seems to be associated with cool temperature and shorter day length. Studies conducted in the field have shown that natural initiation of the inflorescence in pineapple occurs in the late fall or early winter. Gowing (1961) showed that Smooth Cayenne pineapple behaves as a quantitative but not an obligate short day plant. Also, Friend and Lydon (1979) found that 90% of the Smooth Cayenne pineapple plants grown in controlled environments under an 8 hour daylength, flowered after 692 days, while under 10 and 12 hour daylengths, only 25 and 8% respectively of the plants flowered. The period from differentiation, either natural or induced with growth regulators, to appearance of the inflorescence takes about two months with four to five more months required for development and ripening of the fruit (Gowing, 1961; Bartholomew and Kadzimin, 1977).

Cultural practices also affect the susceptibility of pineapple to flower induction. When the pineapple plant grows rapidly as a result of growth stimulation due to irrigation or fertilization (particularly heavy nitrogen fertilization), flower induction is likely to be inhibited (Nightingale, 1942; Gaillard, 1969; Py and Guyot, 1970). Nightingale (1942) stated that a high carbohydrate to nitrogen (C:N) ratio enhanced natural differentiation. Plants having a higher (C:N) ratio were reported to have flowered months earlier than those having a lower (C:N) ratio, regardless of the temperature.

Flower Initiation With Growth Regulators

Artificial flower induction (forcing) in pineapple is a technique developed many years ago by the discovery that pineapple plants could be induced to flower earlier by exposing them to smoke for a period of about 24 hours (Johnson, 1935; Lewcock, 1937; Collins, 1960). Johnson (1935) stated that this practice shortened the growth period from 18 to 11 months. The work of Rodriguez (1932) proved that an unsaturated hydrocarbon gas (ethylene) was the active component in the smoke which induced flowering in pineapple. Since then, the use of growth regulators to promote flowering in pineapple has increased the uniformity of flower induction.

The susceptibility of pineapple plants to the forcing agent depends more or less on the size and/or age of the plant. Experiments conducted on Smooth Cayenne showed that the larger the plant, the more susceptible it was to a chemical forcing agent (Py and Tisseau, 1965; Py et al., 1968; Py and Guyot, 1970). However, Py and Guyot (1970) indicated that medium sized plants were easier to force than very large ones. Bondad (1973) found that one and two-month old plants did not respond to ethephon treatment (50 mg per plant) while older plants (5 to 8 months) flowered readily. However, Aldrich and Nakasone (1975) reported that larger quantities of calcium carbide (a source of acetylene) were required to force older or more vigorously growing pineapple plants than the younger ones.

The ease of floral initiation is also influenced by the nitrogen status of the plant at the time of forcing (Py and Guyot, 1970; Guyot and Py, 1970b; Aldrich and Nakasone, 1975). If the nitrogen content of the leaves reaches a certain level, a greater quantity or multiple applications of the forcing agent is required to achieve a high flowering percentage. The time interval between the last application of nitrogen and the day of forcing also influences the effectiveness of the chemical forcing agent. For example, a lower percentage of flowering was obtained from calcium carbide application to pineapple plants which had been fertilized a month earlier (Aldrich and Nakasone, 1975). Guyot and Py (1970b) found that the normally effective concentration of ethephon (2 kg/ha) became insufficient with high nitrogen status plants (1.6% in leaf base). They suggested that when forcing agents are to be used to hasten flowering, nitrogen should not be applied in the preceeding one to one and a half months.

The effect of temperature on the flower induction of pineapples with ethephon has also been investigated. Conway (1977) found that floral initiation significantly ($P=0.05$) decreased with increasing night temperature. His results showed that mean percentage of flowering averaged over duration of exposure to temperature, was 83% in plants exposed to 20°C, and 75 and 62% in plants exposed to 25 and 30°C respectively. Similar results have been obtained by Glennie (1979) who reported that a maximum air temperature of 28°C on the day of application appeared to be an upper limit for 100% induction, provided that the difference between the maximum day and the minimum night temperature on the day preceeding treatment application did not exceed 10°C.

Forcing Agents and Method of Application

As was indicated earlier, the enhancement of premature flowering in pineapple by chemical treatment is beneficial. In many developing countries calcium carbide is commonly used to induce flowering because it is inexpensive and easy to apply to a single plant. Calcium carbide, in contact with water liberates acetylene according to the following reaction: $CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$. Lewcock (1937) indicated that research conducted in Hawaii showed that a water solution containing acetylene gas was equally as effective a forcing agent as ethylene. Acetylene can be used to force pineapple plants into flower at almost any stage of their growth, provided the plants are well established (Lewcock, 1937). Granulated calcium carbide or a water solution of acetylene acts most effectively if applied in the center (heart) of the plants (Lewcock, 1937; Teisson, 1979). Aldrich and Nakasone (1975) reported that the percentage of flowering obtained from night application of acetylene was significantly higher than that obtained from day application; they suggested that the low percentage of forcing obtained from day application was due to:

a) Low susceptibility of the plants to the forcing agent during the day.

b) A lower rate of movement of the chemical into the plant tissue during the day than at night (a greater number of stomata usually remain closed during the day in pineapple.)

c) A combination of the two situations mentioned above. Calcium carbide is usually available in ground and pelleted forms and is applied at a rate of approximately 0.1 gm per plant; the presence of water in the heart of the plant at the time of application is necessary for the production of acetylene (Anonymous, 1974). The reaction of carbide with water produced heat and usually causes damage to some heart leaves of the pineapple plants (Anonymous, 1974). A large quantity of water (about 3,000 litres/ha) is required to dissolve calcium carbide and promote subsequent acetylene production (Teisson, 1979). Another limitation of calcium carbide is that it causes plants to become more susceptible to *Phytophtora* sps. (Lacoeuilhe and Guyot, 1979). The use of calcium carbide is also labor and time consuming.

Beta-hydroxyethylhydrazine (BOH) has also shown to be an effective forcing agent and is most reliable when applied to the heart of the plant at a rate of 0.1 gm per plant (Py and Guyot, 1970). The results are less consistent when BOH is sprayed over the whole plant. In commercial use, BOH was applied in the evening at a rate of 45 mg active ingredient per plant; however, some phytotoxic symptoms such as burning of the heart leaves may develop shortly after application of BOH. BOH is not registered for use in most areas because it is expensive and has been reported to be a potential carcinogen (D. Bartholomew, personal communication).

Ethephon (2-chloroethylphosphonic acid) is a liquid that gradually decomposes at a minimum pH of 4.5 to ethylene, Cl^- and phosphate after absorption by plant leaves (Py and Guyot, 1970). The reaction for decomposition (Maynard and Swan, 1963; Yang, 1969) is:

$$Cl{-}CH_2{-}CH_2{-}\overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle O^-}{|}}{P}}{-}O^- + H_2O \text{ (or } OH^-) \rightarrow Cl{-}CH_2{-}CH_2{-}\overset{O^-O^-}{\overset{|\,/}{\underset{\underset{\underset{\displaystyle H\;\;H}{/\;\backslash}}{\overset{|+}{O}}}{P}}}{-}O{-} \rightarrow$$

$$Cl^- + CH_2{=}CH_2 + H_2PO_4^- \text{ or } (HPO_4^{=})$$

Because of its rapid decomposition into ethylene at higher pH values, ethephon provides a practical way to stimulate an ethylene induced response in plants and as a result, it is widely used in agriculture and in physiology (Edgerton and Blampied, 1968; Cooke and Randall,1968; Warner and Leopold, 1969; Yang, 1969; Py and Guyot, 1970; De Wilde, 1971; Bondad, 1976).

Spraying pineapple plants with ethephon at rates of 1.1 to 4.5 kg/ha (1 to 4 lb/acre) induced nearly 100% flower formation in pineapple (Cooke and Randall,1968; Guyot and Py, 1970a). In a forcing study of pineapple using ethephon, Py and Guyot (1970) found that ethephon was effective regardless of the method of application; they conlcuded that foliar application (spraying the whole plant) was the most effective. However, good forcing results have been obtained when it was applied in the center of each plant (Wee and Ng, 1971; Bondad, 1973; Dass et al., 1975; Dass et al., 1976; Norman, 1977; Bartholomew, 1977).

Many efforts have been made to increase the efficacy of ethephon. The addition of 2% urea and 0.04% calcium carbonate to a solution containing 10 ppm of ethephon increased its efficacy as a forcing agent of pineapple in India (Dass et al., 1976). The solution was applied at the rate of 50 cc so that only 0.5 mg was required to induce flowering. It was believed that urea enhances absorption of ethephon into the plant (Yamada et al., 1965) and may also increase the rate of breakdown (Dass et al., 1975; Anonymous, 1973; Aubert, 1973).

In the absence of urea it has been possible to obtain more than 90% forcing (at about 50 days after treatment) when 2.5 mg ethephon were applied per plant, in an application limited to the center of each plant (Dass et al., 1975). In Malaysia, ethephon forcing was also found to be superior to acetylene or SNA; the plants flowered more quickly and uniformly when forced with ethephon at rates of 10, 20 and 40 mg per plant (Wee and Ng, 1971). They found that at 40 days after application, ethephon treated plants had 97% flowering while carbide treated plants resulted in only 64% forcing. After 50 days, ethephon treatment was still superior.

Ethylene gas (C_2H_4) has also been used successfully to induce flowering in pineapple (Cooper and Reese, 1941; Cooper, 1942; Derycke, 1974). However, ethylene is only used on one plantation in Hawaii because of the specialized equipment required for its application. There are few published data on its use as a forcing agent because of the difficulty encountered in applying it. One of the main obstacles encountered is the difficulty of obtaining intimate contact between the gas and the adsorbent (usually activated carbon); it has been greatly improved with the adoption of the Air Liquid injector (Derycke, 1974).

Ethylene possesses some of the specific properties of a typical plant growth hormone, and it is involved in a variety of plant biochemical activities of physiological importance (Burg, 1962; Pratt and Goeschl, 1969; Abeles, 1973; Osborne, 1977; Lieberman, 1979; Yang, 1980).

Naphthalene acetic acid (NAA) and its sodium salt (SNAA) are also used to induce flowering in pineapple. Clark and Kerns (1942) reported that floral initiation in pineapple could be achieved in advance of the normal period by application of alpha-naphthalene acetic acid (NAA), naphthaleneacetamide or naphthalenethiocetamide. When NAA was applied as a foliar spray at a concentration of 10 ppm, forcing occured, but at concentration as high as 1,000 ppm, floral initiation was inhibited (Clark and Kerns, 1942). In Puerto Rico, NAA and 2, 4-dichlorophen-oxyacetic acid, at a rate of 0.25 mg per plant, were equally effective in inducing flowering (Van Overbeek, 1945).

In Queensland, spring and early summer applications of NAA, at a rate of 0.25 mg per plant, forced flowering; however, in Autumn, when the heart of the plant was filled with water, 0.5 mg of NAA per plant was recommended (Groszman, 1950). In India, application during March of 0.4 and 0.8 mg per plant of NAA was found more effective for maximum flower induction than 0.25 mg per plant. However, when NAA was applied in May, the lower rate was found most effective (Dass et al., 1970). In the field, when NAA is applied as a foliar spray, the recommended rate of application is 1 to 2 mg per plant. In warm climates, a second application of NAA must follow the first one by 7 to 8 days (Py and Guyot, 1970).

Sunlight, even at low intensity, causes the destruction of NAA especially when the temperature is high (Gowing et al., 1962). Despite this fact, day application has proven to be the most effective.

NAA is absorbed and translocated very quickly from younger leaves to the apical meristem (Gowing et al., 1962) so any rain that follows its application does not alter its action (Py and Tisseau, 1965).

Flowering has been induced in the 'Cabezona' cultivar by placing plants horizontally for 3 days (van Overbeek and Cruzado, 1948). The authors speculated that a reorientation of the endogenous auxin occured and, as a result, floral initiation took place. Later, Burg and Burg (1966) showed that auxins such as NAA induce ethylene formation and that ethylene rather than auxin, was the probable agent that caused pineapple to flower. When Burg and Burg (1966) applied NAA at 0.5 mg per plant into the center of each plant, the plants produced from 13 to about 35 ml of ethylene 7 days after treatment. Control plants which did not receive NAA produced no measurable amount of ethylene during the same period of time.

III. MATERIALS AND METHODS

Two field experiments were designed to study the effects of rate and concentration of ethephon on inflorescence initiation in pineapple. The experiments were conducted in Dole Company field 4133 (where planting was primarily for production of fresh fruit), near Waipio on the island of Oahu. The soil in this field belongs to the Wahiawa silty clay series which is a Tropeptic Eutrustox of the order Oxisol. The elevation was about 150 m (500 ft.). The two experiments were separated from each other by a buffer area of approximately 1.52 m (5 ft.).

Fruit crowns (tops) of the pineapple cultivar Smooth Cayenne were planted and maintained in accordance with standard plantation practices by Dole workers. The crowns were planted between March 6 and March 13, 1980 at an interplant spacing of 21.6 cm (8.5"), giving a total of 76230 plants per hectare (30492 plants per acre). The distance between bed centers was about 1.22 m (48") and the rows in the beds were 0.56 m (22") apart. At the time the experiment was installed (January 21, 1981), the plants were approximately 10 month old and none of them had produced flowers or fruits.

Before forcing took place, and up to six weeks after forcing, the plants were treated with bi-weekly application of nitrogen in order to sustain normal growth. The total amount of nitrogen applied during the crop cycle was about 618 kg/ha (Gordon Young, personal communication). The estimated average plant weight prior to forcing based on block average was 2.5 kg (5.5 lb) which is considered an optimum plant weight for forcing (Gordon Young, personal communication).

The experimental design used was a randomized complete block with 4 replications and 5 treatments. Each replication included 56 plants per row (112 plants per bed). Data were taken from the center 50 plants in each row or 100 plants per bed.

In both experiments, ethephon was applied on January 21, 1981 (10 months after planting) on a bright sunny day by means of a stainless steel pressure sprayer having a capacity of 11.38 liters (2.5 gallons). Two tee-jet nozzles were spaced 0.46 m (18") apart to simulate boom spray application. The air pressure was not regulated. Spray drift was minimized by holding the nozzles of the sprayer close to the pineapple leaves during spraying. An attempt was made to apply the solution uniformly to all plants by making a minimum of two passes over the treated plants. Chemical solution was based on concentration of active ingredient on a weight to volume basis and were prepared just prior to application.

In Experiment one, the treatment consisted of ethephon rates from 0.5 to 10.0 mg per plant (see fig. 1). The chemical was mixed with a 4% urea solution and applied in a total volume of 937 liters per hectare (100 gallons/ acre). One hundred plants per plot were treated. A total of 2,000 plants were required.

In Experiment two, ethephon, at the rate of 5 mg per plant was applied in about 2.45, 4.29, 12.27, 30.64 and 91.94 ml per plant or 187, 327, 937, 2336 and 7009 liters per hectare respectively (20, 35, 100, 250 and 750 gallons per acre).

As in Experiment one, one hundred plants per plot were treated. The different levels of ethephon were applied in 4% urea solution. A total of 2,000 plants were also used in this experiment.

In both experiments, no control treatment was considered necessary because the effectiveness of ethephon had been established in several earlier experiments. Secondly, the main objective of these experiments was to compare different rates and concentrations of ethephon to determine the minimum and most effective dosage of ethephon-urea solution to be used for forcing.

Data Collection

Field Observation

Visual observations of the effects of different rates of ethephon and carrier on the percentage of flower initiation with ethephon-urea sprays started about two months after treatment. Counts of the number of inflorescences were made weekly and the developmental stage of each inflorescence was recorded. Nine successive stages are recognized by the pineapple industry for use in characterizing inflorescence development. Knowledge of the development of these stages can help in predicting harvest date at some later time. The identifiable stages are: 'half inch open heart' where the inflorescence is just visible and the heart leaves have opened about a half inch in diameter; 'one inch open heart' where the heart leaves are opened one inch in diameter; 'early cone' stage where the inflorescence is shaped like a small cone and has just started to emerge above the leaves in the center of the plant; 'mid cone' stage where a definite cone protrudes from the center of the plant; 'late cone' stage where the inflorescence is visible but no flowers have opened; 'early flower' stage where not more than one third of the flowers have opened; 'mid flower' stage where half or more of the flowers have opened; 'late flower' stage where about two thirds of the flowers have opened, and lastly, the 'dry petal' stage where all the petals of the florets become dry.

The effectiveness of the treatment (expressed as percentage of plant treated) was based on counts of 100 plants per plot.

Field Harvest

The fruits were harvested when 25 to 50% of the fruit had become yellow, the stage which pineapple plantation workers identify as shell color 2 to 4.

Sample Size

From an estimate of the between fruit variance available from another experiment of a similar population (D. Bartholomew, personal communication) it was possible to estimate the minimum number of fruits required to obtain an accurate estimate of the effect of treatments on fruit shape, weight, brix and titratable acid. The following equation was used for the estimation.

$$N = \frac{(Z\alpha/rd)(Vs/\bar{y})}{1-(Z\alpha/rd)(Vp/\bar{y}^2)} \qquad \text{(Gomez \& Gomez, 1976)},$$

where N is the required sample size, Vp the variance among plots of the same treatment, Vs the variance among fruits in the same plot, r the number of replications, $\bar{y}$ the true mean, and $Z\alpha$ the value of the standardized normal variate corresponding to the level of significance α=0.05. However to estimate slip and sucker numbers per plant, the equation of Peterson and Calvin (1965) for normally distributed variables which is based on plot variance was used to estimate the required sample size. The appropriate sample size was calculated by the following equation.

$$n = \frac{4\sigma^2}{L^2} \qquad \text{(Snedecor and Cochran, 1967)}$$

where n = sample size

σ^2 = variance among sampling units within plots (an estimate of the population variance), and

L = allowable or selected limit

It was calculated that a sample size of 12 fruits would provide an accurate estimate of the effect of treatment of fruit characteristics.

Each fruit and its crown were separately weighed, the length, the number of fruitlets per long spiral (multiplied by eight to estimate fruitlet number per fruit), and the top and bottom diameters were measured. Data on fruit 'cannery size' and on fruit abnormalities were taken. Fruit 'cannery size' segregates the fruit on the basis of diameter large enough to fit into a no.2½ size can (fruit with a maximum diameter of about 10.8 cm), those less than $2\frac{1}{2}$ size that will fit into a no.2 can (fruit with a maximum diameter of 10.4 cm) and those too small to fit either can. Fruits can also be graded on the basis of length into One tall, Two tall, and Two and one-half tall, but such grading was not done in these experiments. Special rings of different diameters are used to determine the cannery size of each fruit.

A normal fruit is one which is free from any major defects such as more than one crown, crooked crown, dwarfed, sunburn damage, cracked shell, and the mutation "Bottle neck."

The number of slips and suckers produced per plant was also recorded after fruit harvest.

Twelve fruits from each plot were cut in half with a knife and two longitudinal opposite slices from each fruit were taken. The juice from each fruit was pressed from the tissue with a manual juicer and placed in a clean vial after proper labelling. Percentage of sugars in the juice in terms of soluble solids was measured, using a hand refractometer. Percentage acid in the juice as citric acid was determined by titrating a 10 ml. aliquot of the juice sample against 0.1549 N sodium hydroxide, using phenolphthalein as the indicator. The weight of a 10 ml sample of pineapple juice is estimated to be 10.5 g and the percentage of citric acid was calculated by the following equation.

$$\% \text{ Citric acid} = \frac{\text{ml NaOH x N x 0.06404}}{\text{weight of sample (g)}} \times 100$$

where N = normality of NaOH, and 0.06404 is the grams of citric acid ($H_3C_6H_5O_7$) titrated by one milliliter of 1 N NaOH.

All data were analysed by analysis of variance and the treatment means were separated using Duncan's multiple range test. Means presented in the tables were treatment means calculated from the original data. The flowering response and the harvested fruit data were expressed in percentages (A) and statistical analysis was done on transformed arcsin A (degrees). However, the actual interpretation was based on percentage of plants flowering or harvested.

In Experiment two, the plot representing treatment three (12.27 ml solution treatment) of replication four was treated as a missing plot because the flowering response was negligible (presumably due to the fact that no treatment was applied) even 99 days after treatment. Therefore the following missing plot formula was used to estimate the value of the missing plot in a randomized complete block design.

$$x = \frac{rB_o + tT_o - G_o}{(r-1)(t-1)} \qquad \text{(Gomez and Gomez, 1976)}$$

where r = number of replications,

t = number of treatments,

B_o = total of the block (replication) containing the missing unit,

T_o = total of the treatment containing the missing unit,

G_o = total of all observations.

Then the adjusted treatment sum of squares was calculated by subtracting the correction factor for bias (B) from the treatment sum of squares. B is computed as follows:

$$B = \frac{[B_o - (t-1)x]^2}{t(t-1)}$$

Simple linear correlation and regression analyses were utilized to determine the degree of relationship between some of the different variables.

IV. RESULTS AND DISCUSSION

Average monthly data for the period from forcing until harvest (January 1981 through August 1981) was obtained for a nearby station (Waipio, Benchmark Soils Project, University of Hawaii) and are presented in Table 1. Temperature differences between the station and the field sites would be very small. Maximum air temperature for the day prior to forcing was 25°C below that recorded on the day of forcing. The maximum air temperature recorded on the day of forcing was 27°C. Glennie (1979) observed that induction is better when the difference between the maximum air temperature on the day of forcing and the minimum for the previous night is small (less than 10°).

In this experiment, the minimum air temperature on the day of forcing and the day before remained constant at 17°C. No rain was recorded.

Ethephon, at the rates and concentrations used, induced some inflorescence development in all treatments. In most plants, the development of the inflorescence was normal, i.e. most of the flowers that resulted from daytime application of ethephon at the rates and concentrations used were not dwarfed or misshapen. Since the ethephon rates were relatively low, no phytotoxic symptoms were

Table 1

Average Weather Data for A Field Near the Experimental Area
(Waipio Benchmark Soils Project, University of Hawaii

MONTH	AIR TEMPERATURE		WIND RUN	DAILY SOLAR RADIATION
	MAXIMUM	MINIMUM		
	C		-km/hr-	-langleys-
January	28.92	18.63	7.85	283.39
February	27.92	18.22	11.33	345.43
March	28.33	17.75	9.21	416.09
April	28.89	18.21	8.53	465.43
May	29.40	19.53	8.82	449.52
June	30.67	21.04	7.82	502.68
July	31.56	21.03	7.42	514.18
August	32.07	21.31	6.48	461.76
September	33.13	21.30	6.66	440.64

observed on the leaves.

The results of the two experiments are reported separately in the following sections.

Effect of Ethephon Rates on Inflorescence Development

The effect of different rates of ethephon on inflorescence initiation in Smooth Cayenne pineapple was determined weekly, beginning 50 days after treatment. Data on flowering were based on the 'half inch open heart' stage. The cumulative percentage of flowering increased with time at all rates of ethephon (Figure 1). None of the rates used induced 100% forcing at 120 days after treatment. However, the percentage of plants forced increased with increasing rate of ethephon (Figure 1). Percentage of flowering was significantly greater at the 10 and 5 mg rate than at the other 3 rates. All rates would be considered a poor force, but the forcing percentage of the three lower rates are unacceptably low. The low percentage of forcing at rates below 5.0 mg ethephon demonstrates that a certain quantity of ethephon is necessary to initiate inflorescence development in pineapple. Thus a rate at or below 2.5 mg ethephon per plant would be insufficient when applied as a spray over the whole plant.

It can be seen from (Fig. 1) that the higher the rate, the earlier the appearance of the inflorescence,

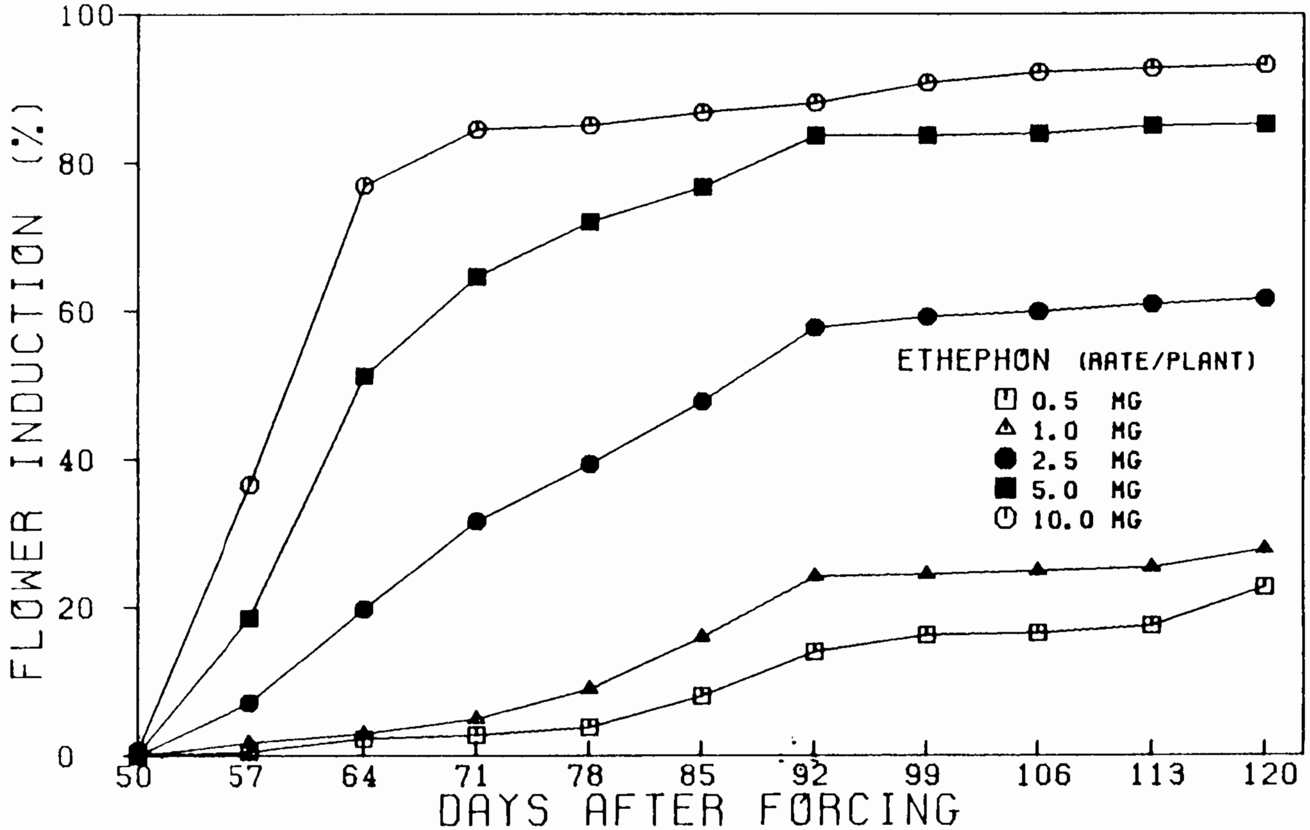

Figure 1. Rate of Inflorescence Emergence of 'Smooth Cayenne' Pineapple after forcing with Different Rates of Ethephon.

the steeper the slope, and the earlier the peak was reached. Thus, in addition to forcing a greater number of plants, a higher rate of ethephon would reduce the number of harvest rounds better than lower ones. Percentage of flowering for the 10 mg treatment plateaued at about 71 days (Figure 1), followed by the 5 mg treatment that reached its plateau about 92 days after treatment. It was not until 99 days after treatment that the response curves of the three lower rates began levelling-off.

Similar results were obtained in the French West Indies by Guyot and Py (1970b) who also found that the higher the rate of ethephon, the steeper the slope and the earlier the plateau was reached. The data were also similar to those reported by Bondad (1973) who obtained a flowering peak at about 70 days after forcing with ethephon at the rate of 50 mg per plant.

In the pineapple industry, forcing is generally expected to be near 100%. Such forcing results are achieved with two applications of ethephon at 1.125 kg/ha (1 lb/A) in a total volume of 2336 l/ha (250 gal/A) by means of boom sprayers (Gordon Young, personal communication).

However the 10 mg rate (0.76 kg/ha) used in this experiment did not force 90% of the plants. This could have been due to the lower quantity of ethephon used or to the lower volume of solution applied (935 l/ha^{-1}).

Another reason for the poor forcing result could be due to a poorer coverage of the pineapple leaves during treatment application. It is often more difficult to obtain uniform coverage by means of the type of sprayer used than it is with boom sprayer. It is also possible that the warm temperature (27°C) reduced plant susceptibility to ethephon as has been reported by Glennie (1979).

Glennie (1979) obtained over 90% forcing with 6 mg ethephon per plant when 50 ml of a solution containing 2% urea and 0.5% borax were poured into the plant heart. The reasons for the discrepancy between the data reported here and those of Glennie (1979) may be due in part to the difference in the method of application, the lower pH (3.0) of the solution used in this test and possibly to the lower volume of solution used per plant.

In India, Dass et al. (1975) obtained excellent forcing results with ethephon, at the rate of 1.25 mg per plant. Dass et al. (1975) applied 50 ml solution per plant, a volume 4 times greater than that used in this experiment, and the ethephon solution was poured directly into the center of each plant. Other factors that may have contributed to the difference between the two trials are differences in cultivar ('Kew' in India and 'Smooth Cayenne' in Hawaii), age, plant size and nutrition.

The cumulative number of fruits harvested corresponded nearly to the percentage of plant forced (Figure 2). Again the best results were obtained with the 10.0 mg treatment.

The first fruit was harvested 7 months after treatment. The 5.0 and 10.0 mg treatments markedly advanced the time of harvesting (Figure 3). Mean harvest date was shortened by approximately one week at the two higher rates compared to the lower ones (Table 2). The fruit ripened fairly uniformly at the two higher rates, but ripening was less uniform at the lower rates. A harvest peak for these two higher rates was reached 222 days after treatment (Figure 3). The actual peak for the lower rates occurred between 222 and 229 days after treatment.

The average number of days from forcing to harvest was 221, a value higher than that reported by Wee and Ng (1971) or Dass et al. (1975), but normal for Hawaii when plants are forced in winter (W.G. Sanford, personal communication). At 166 days after forcing, Wee and Ng (1971) harvested more than 90% of the available fruits, while in India, 90% of the fruits were harvested in 205 days (Dass et al., 1975). The lower the rate of ethephon, the longer was the average period between forcing and harvesting which probably in part explains the relationship between rates of ethephon and average fruit weight.

There was no significant difference in fruit weight between the treatments in this study (Table 2; Appendix

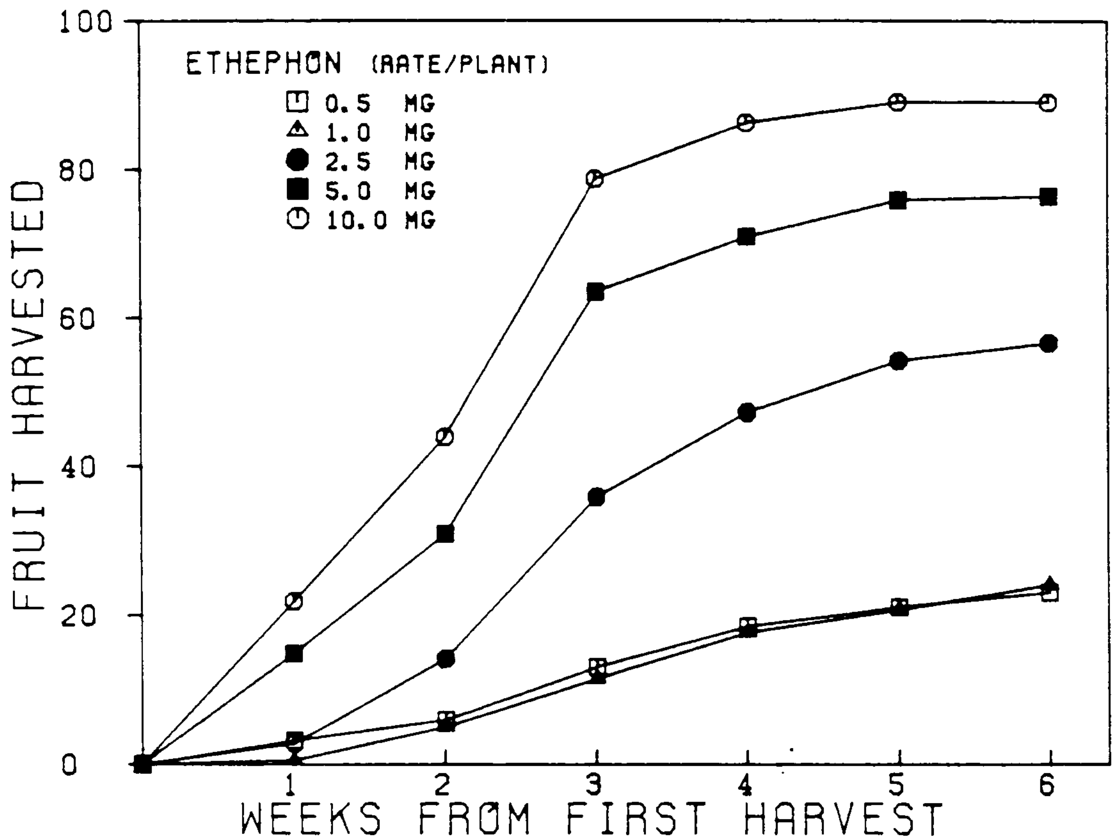

Figure 2. Cumulative Number of Ripe Fruit Harvested After Forcing with Different Rates of Ethephon. Data are the Means for Four Replications.

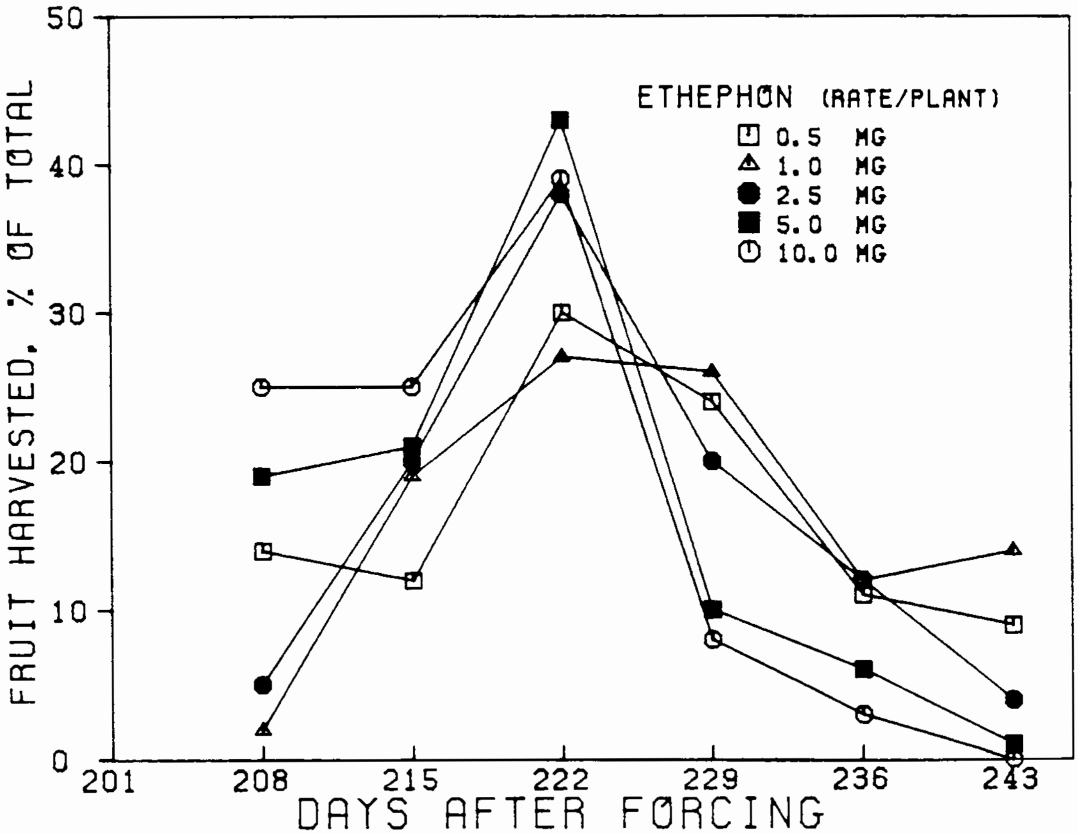

Figure 3. Plant Crop Harvest Curves for 'Smooth Cayenne' Pineapple Forced with Different Rates of Ethephon.

Table 2

Effects of Ethephon Rate When Used As A Flower Inductant on Fruit Characteristics of 'Smooth Cayenne' Pineapple

Ethephon Rate	Forcing to Harvest	FRUIT Weight	FRUIT Length	FRUIT Top Diameter	FRUIT Bottom Diameter	FRUIT Cannery Size	Fruitlets Per Long Spiral	Fruit Defect	Total Soluble Solids	Acid As Citric	Crown
-mg/plant-	-days-	-kg-	cm	cm	cm				%	%	-kg-
0.5	224.4a[+]	1.97a	17.44a	10.46cb	12.33a	2.10a	15.90a	1.38a[++]	15.85a	1.01a	0.282b
1.0	227.5a	1.79b	17.18a	10.29c	12.24a	2.01b	15.33a	1.30a	15.40a	0.99ab	0.300ab
2.5	223.6a	1.79b	17.13a	10.63cb	12.55a	1.98b	15.31a	1.15a	15.55a	0.93abc	0.304ab
5.0	218.2b	1.74b	16.55a	10.75b	12.37a	2.00b	15.19a	1.15a	15.52a	0.91bc	0.306ab
10.0	216.0b	1.74b	16.41a	11.21a	12.45a	2.02ab	15.00a	1.14a	15.14a	0.88c	0.31a

\+ Means within the same column which are followed by the same letter are not significantly different at 5% level as determined by Duncan's Multiple Range Test.

++ Normal fruits were scored as 1.0 and abnormal fruit (crooked crown, multiple crown, dwarfed, cracked shell, bottle neck, and sunburn) were scored as 2.0.

Table 7). However average fruit weight decreased slightly with increasing rate of ethephon, thus confirming the observations of Dodson (1968), Wee and Ng (1971), Norman (1977), Dass et al., (1976), that the growth regulators have no significant effect on mean fruit weights, though there was a perceptible trend towards weight depression due to growth regulator particularly at very high plant populations and/or in low nitrogen regimes.

The results for fruit length (Table 2, Appendix Table 7) were closely associated with fruit weight and the two parameters were highly and significantly ($P = 0.0001$) correlated ($r = 0.81$). The regression line that describes this relationship is shown in Figure 4. The lack of a significant effect on fruit length following application of ethephon is in agreement with the results of Dodson (1968) and Dass et al. (1976).

The mean fruit top diameter increased significantly with increasing rate of ethephon (Figure 5; Appendix Table 7).

Fruit bottom diameter on the other hand did not respond to treatment (Appendix Table 7), a result consistent with the observation of Dodson (1968) that growth regulators do not influence fruit bottom diameter. Apart from the 2.5 mg treatment, there was a slight tendency for the mean fruit bottom diameter to decrease with decreasing

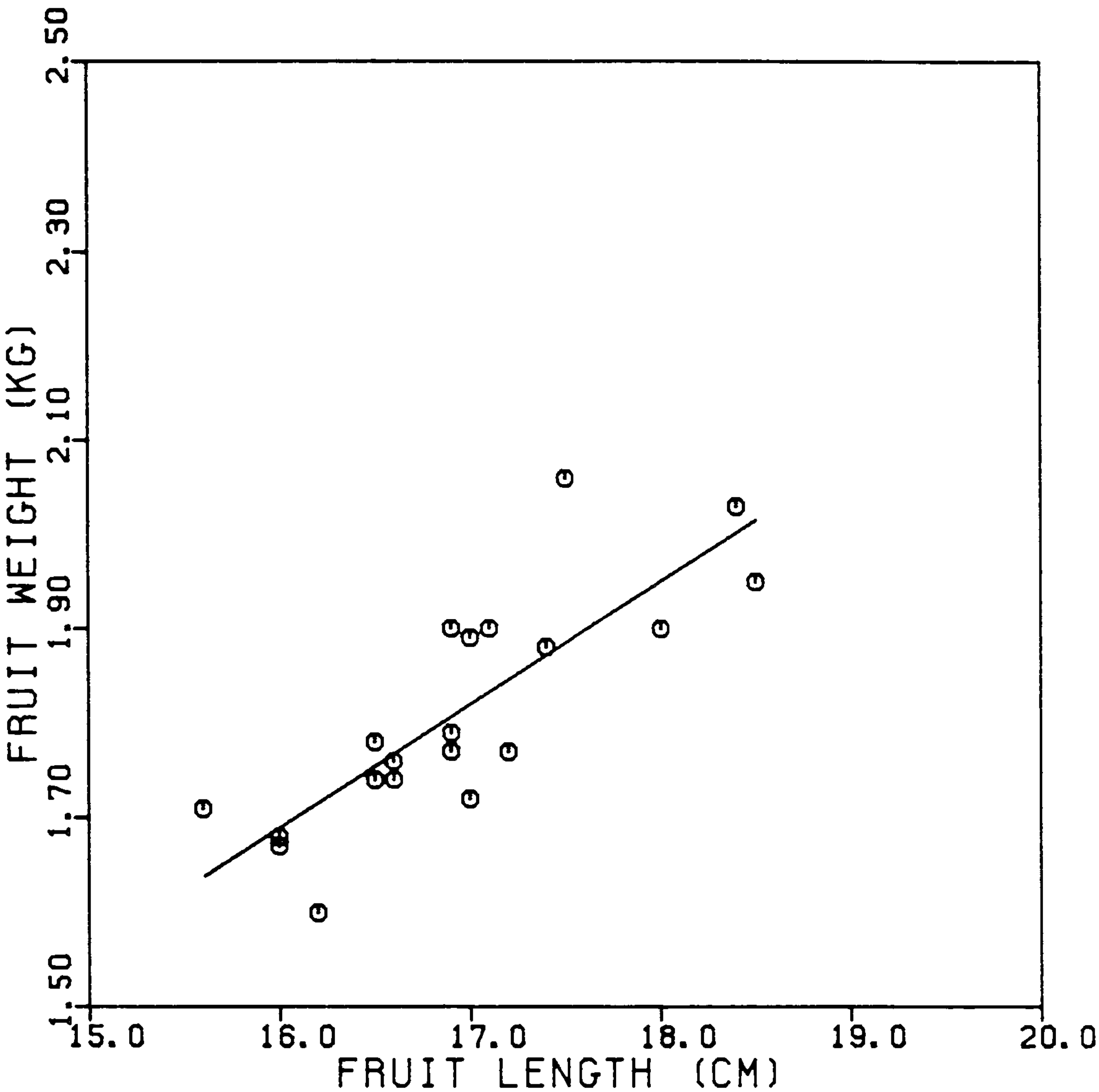

Figure 4. Relationship between Fruit Weight and Fruit Length After Forcing with Different Rates of Ethephon, ($Y = -0.405 + 0.13\ X$, $R^2 = 0.67$)

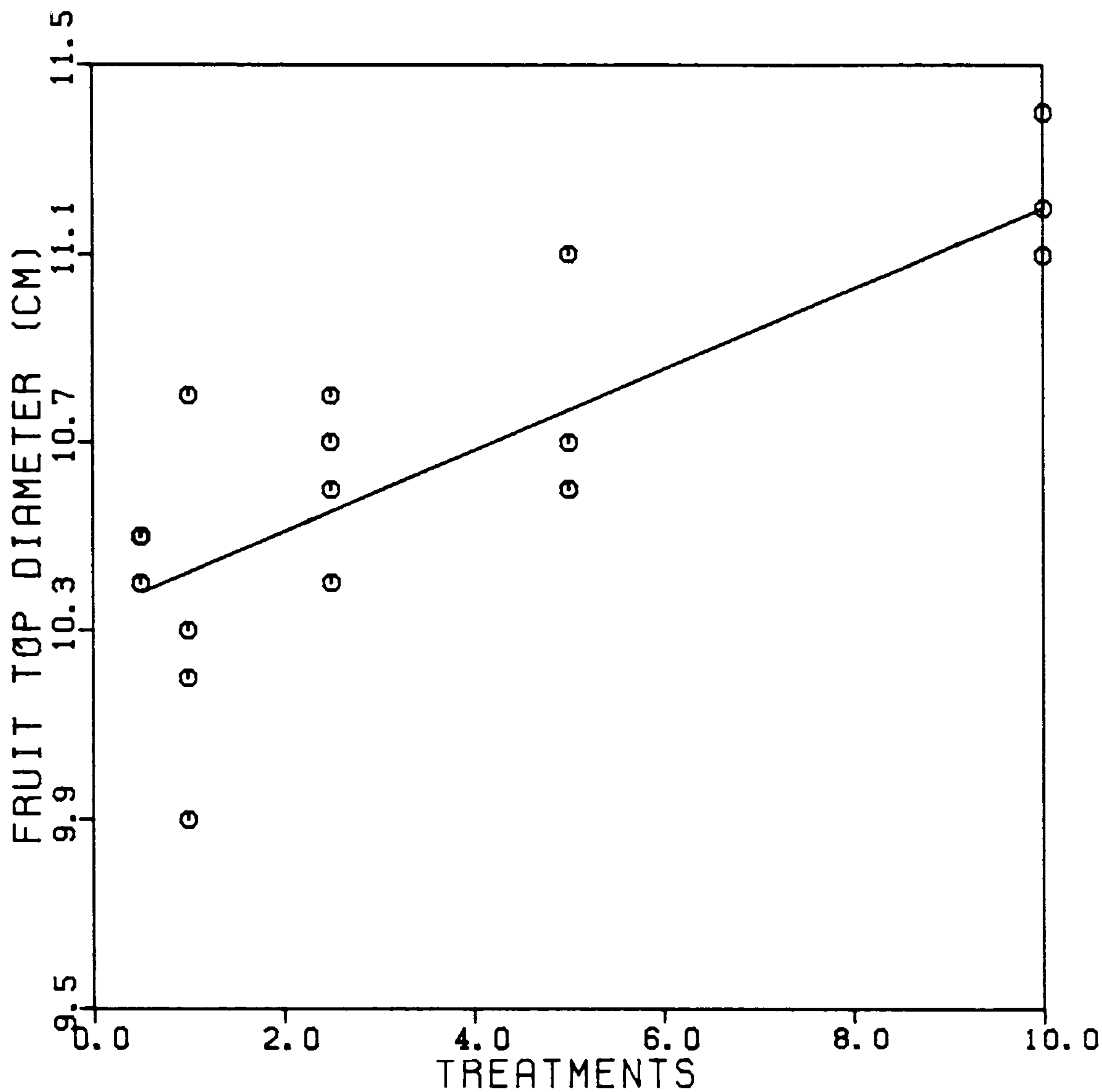

Figure 5. Relationship between Fruit Top Diameter and Ethephon Rate, ($Y = 10.34 + 0.086\ X$, $R^2 = 0.678^{**}$)

rate of ethephon (Table 2).

Fruit cannery size was not significantly affected by treatment (Table 2; Appendix Table 7). The highest mean cannery size was 2.1 and was obtained at the lowest rate of ethephon. Average cannery size was low for plants as large as the ones in this experiment. Data from the Pineapple Research Institute of Hawaii (W.G. Sanford, personal communication) indicated that the best 2½ fruit recovery was obtained at planting densities ranging from 54,340 to 64,220 plants per ha (22,000 to 26,000 plants per acre). The relatively lower percentage of 2½ size fruit obtained in this experiment could be due to the high plant population (76,230 plants per ha) used in the field where this experiment was conducted.

There were no significant differences in the number of fruitlets (eyes) produced per long spiral due to treatment (Appendix Table 7). As in the case of average fruit weight, the mean number of eyes per long spiral tended to decrease with increasing rate of ethephon (Table 2). The number of eyes per long spiral was positively correlated with fruit weight (Figure 6) and fruit length (Figure 7). The correlation coefficient in both was high and highly significant.

There were no significant differences in fruit abnormality among the treatments (Appendix Table 7). However there

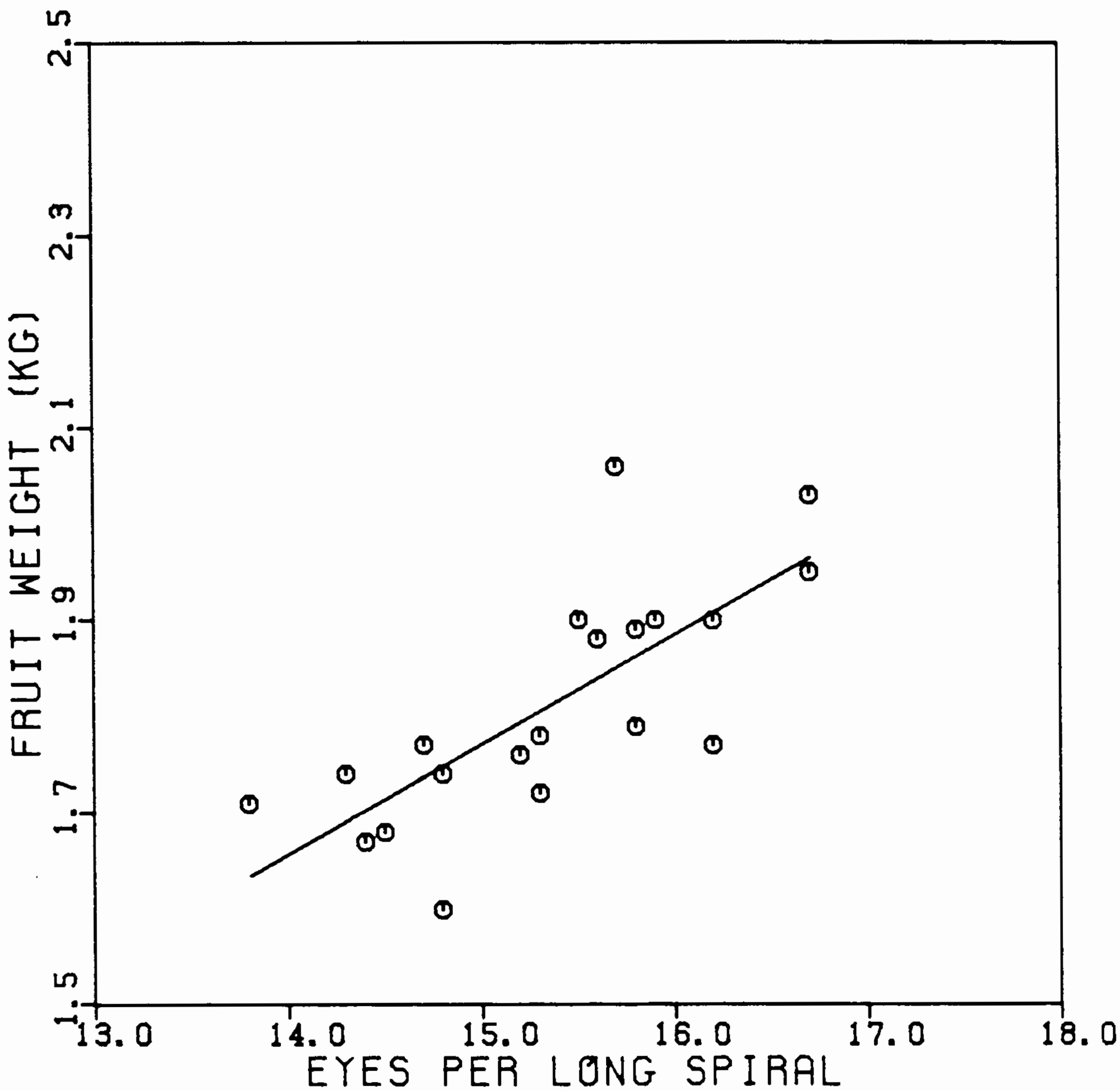

Figure 6. Relationship between Fruit Weight and Number of Eyes (Fruitlets) per Long Spiral After Forcing with Different Rates of Ethephon, ($Y = 0.20 + 0.10\ X$, $R^2 = 0.65$)

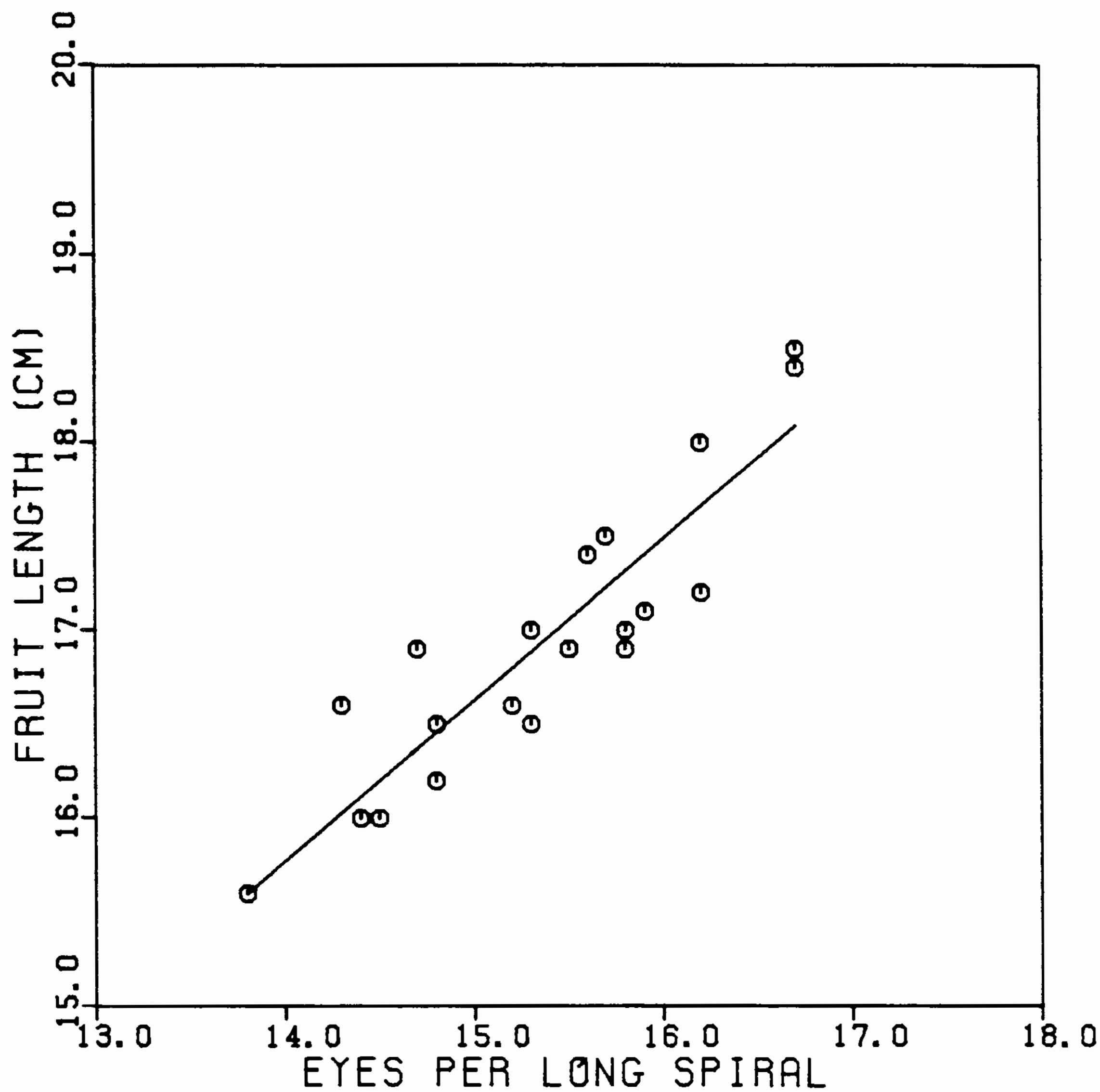

Figure 7. Relationship between Fruit Length and Number of Eyes (Fruitlets) per Long Spiral After Forcing with Different Rates of Ethephon, ($Y = 5.83 + 0.72\ X$, $R^2 = 0.79$).

was a tendency for fruits to become more normal (freedom from any deleterious effect) with increasing rates of ethephon (Table 2). The number of sunburned fruits was negligible because of the high planting density and because the incidence of sunburn tends to be low in Hawaii.

Total soluble solids (°Brix) was not affected significantly by the treatments (Appendix Table 12), thus confirming the data of Dodson (1968) and Norman (1977) who found no significant effect of growth regulators on total soluble solids content. The mean total soluble solids in this experiment was 15.5% which is much lower than the 17.4% obtained by Teisson (1979) in the Ivory Coast. The difference is probably due to the differences in environment between the two locations during the period of fruit development and maturation and to the high planting density used in this experiment.

In contrast with the data for soluble solids, the effect of ethephon on titratable acids expressed as percentage citric acid was significant (Appendix Table 2). Mean fruit acidity decreased with increasing rates of ethephon (Table 2). These results contradict those obtained by Dodson (1968) and Norman (1977) who found an increase in fruit acidity over the control with the use of NAA and ethephon respectively. The reason for the difference in response to forcing agents in the different experiments may be due to the excessive shading which occurred in the plots where a small percentage of the plants were forced. Vegetative plants continue their growth and greatly over shadow fruiting plants after six to seven months of additional growth.

Ethephon treatment did not influence the crown weight (Appendix Table 7). However the mean crown weight tended to increase as fruit weight decreased and the rate of ethephon increased (Table 2). It is common to find a negative correlation between fruit weight and crown weight (D. Bartholomew, personal communication).

Ethephon treatment reduced significantly the number of slips and suckers produced per plant (Table 3; Appendix Table 8). The 5.0 and 10.0 mg ethephon treatments produced only 23 and 38% as many slips as were obtained for the 0.5 mg treatment. A similar but not quite so drastic decline in sucker production was observed at the 5 and 10 mg rates of ethephon. The results agree with the commonly held view and earlier findings (Bondad, 1973; Norman, 1977) that growth regulators decreased the number of slips and suckers produced per plant.

Effects of Ethephon Carrier Rate on Flowering

As in Experiment One, the determination of the effects of ethephon carrier rate at a constant rate of ethephon

Table 3

Effects of Ethephon Rate When Used As A Flower Inductant on Slip and Sucker Production of 'Smooth Cayenne' Pineapple

ETHEPHON RATE+	SLIPS PER FORCED PLANT	SUCKERS PER FORCED PLANT
-mg/plant-		
0.5	1.75a++	1.05a
1.0	0.95b	1.04a
2.5	0.53cb	0.83b
5.0	0.41c	0.58c
10.0	0.67cb	0.79b

\+ The rates used contained 4% urea (w/v) and 12.3 ml ethephon solution.

++ Means within the same column which are followed by the same letter are not significantly different at 5% level as determined by Duncan's Multiple Range Test.

per plant (5.0 mg) on inflorescence initiation started 50 days after treatment. In all treatments, the percentage of flowering increased in a curvilinear fashion with time (Figure 8). The higher the volume of solution, the earlier the appearance of the inflorescence, the steeper the slope and the earlier the peak was reached. The plateau for the 91.9 ml and 30.6 ml per plant treatments was reached at 71 days after forcing (Figure 8). Percent flowering for the 12.3 ml treatment plateaued about 92 days after treatment, while the two lower volume treatments had not reached a plateau at 99 days after treatment.

The final flowering percentages for the two higher volume treatments were 90 and 94%, and the two were not statistically different from each other. Flowering percentages at the three lower volume treatments were significantly different from each other up to 92 days after treatment. The two lower volumes of ethephon solution induced less than 65% of the treated plants to flower 92 days after treatment. This generally would be considered a poor force.

The results of this experiment show that higher volumes of ethephon solution at a constant rate of ethephon per hectare markedly enhanced the efficacy of ethephon. However, none of the treatments resulted in 100% forcing. This result can be explained in part by the lack of uniform

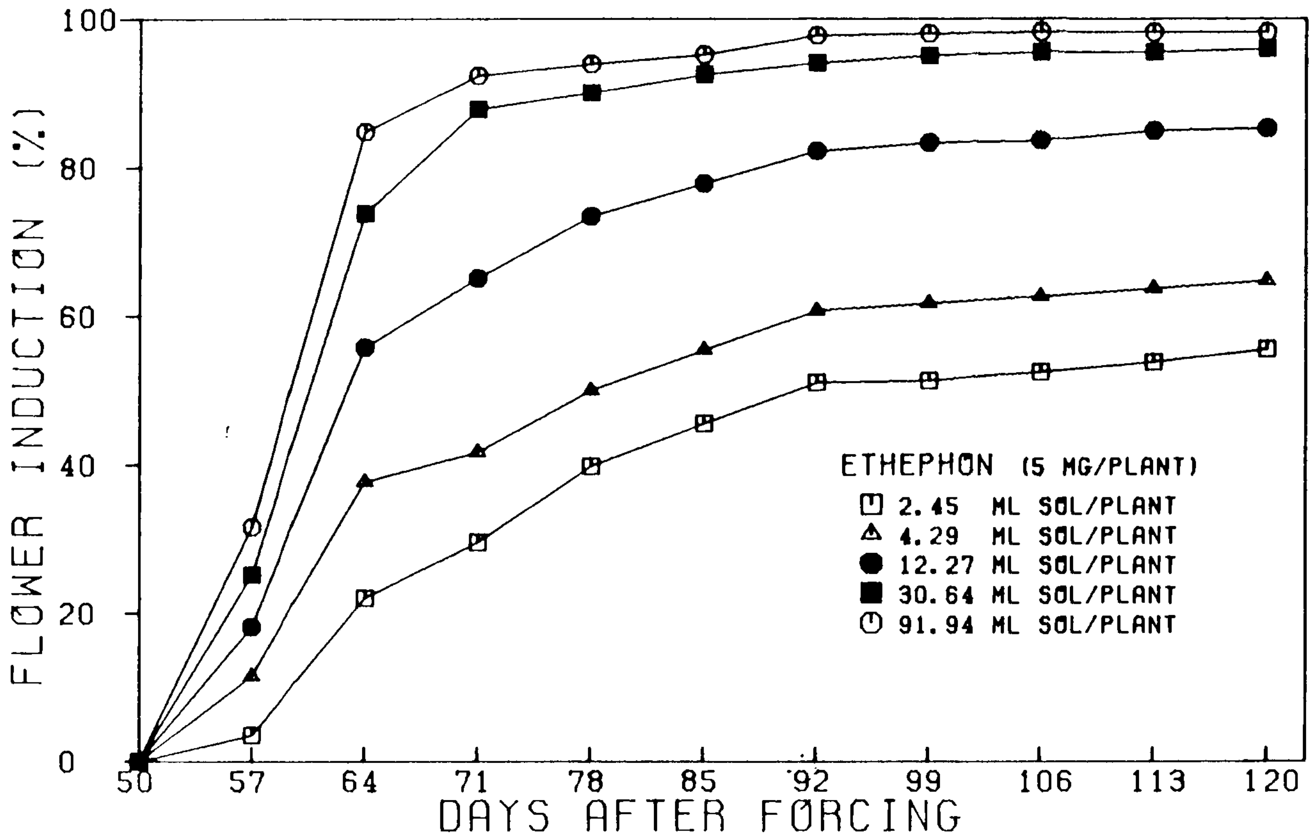

Figure 8. Rate of Inflorescence Emergence of Smooth Cayenne Pineapple After Forcing with Different Rates of Ethephon Carrier.

coverage of the leaves by the hand sprayer application. Also a few smaller plants did not respond to the ethephon treatment, possibly because they were masked by larger ones and therefore did not receive an adequate amount of ethephon solution or because they were too small to respond to ethephon. Bondad (1973) and Conway (1977) were unable to force 2 month old pineapple plants. Earlier, Loomis (1932) and Salisbury (1963) reported that many higher plants will not flower in a favorable environment unless they reach a certain age or physiological maturity. The relatively lower forcing results obtained with lower volumes of ethephon solution is possibly due to the fact that there was insufficient coverage of the pineapple leaves.

The forcing results obtained with the two higher volume treatments are close to those obtained by Py and Guyot (1970) who applied ethephon at a constant rate of 88 mg per plant in 44, 88 and 176 ml water per plant (2,000, 4,000 and 8,000 liters per hectare) and obtained 95, 90 and 75% flowering respectively. However the results reported here are inferior to those reported in India by Dass et al. (1976) who obtained 100% forcing with ethephon at rate of 0.5 mg per plant in conjunction with 2% urea and 0.04% $(Na)_2CO_3$ in an application limited to the center of the plant. The difference in results could be due to differences in degree of susceptibility of the plants to the forcing agent and to the method of application of ethephon. Adjusting the ethephon solution pH to 9.0 has been reported to improve forcing in India (Dass et al., 1976) and in Australia (Glennie, 1979). Warner and Leopold (1969) demonstrated that ethylene is released more rapidly from ethephon when the pH is adjusted to 9.

Effect of Ethephon Carrier Rates on Fruit Maturation And Fruit Characteristics

The cumulative number of fruit harvested (Fig. 9) increased with increasing volume of solution applied. The best results were obtained with the 30.6 and 91.9 ml treatment at about 215 days, followed by the other treatments that reached their harvest peak about 222 days after treatment.

An effect of ethephon on the uniformity of ripening was evident particularly with those plots that received the 91.9 ml treatment. During the second week of harvest (208 days after treatment), 25 and 27% of the fruits were harvested from plots that received the 30.64 and 91.9 ml treatments respectively, while less than 15% of the fruits were harvested from the lower volumes of ethephon treatment (Fig. 10).

As in Experiment one the first harvest was obtained 7 months after treatment. The three higher volumes of ethephon carrier advanced the time of harvesting (Table 4).

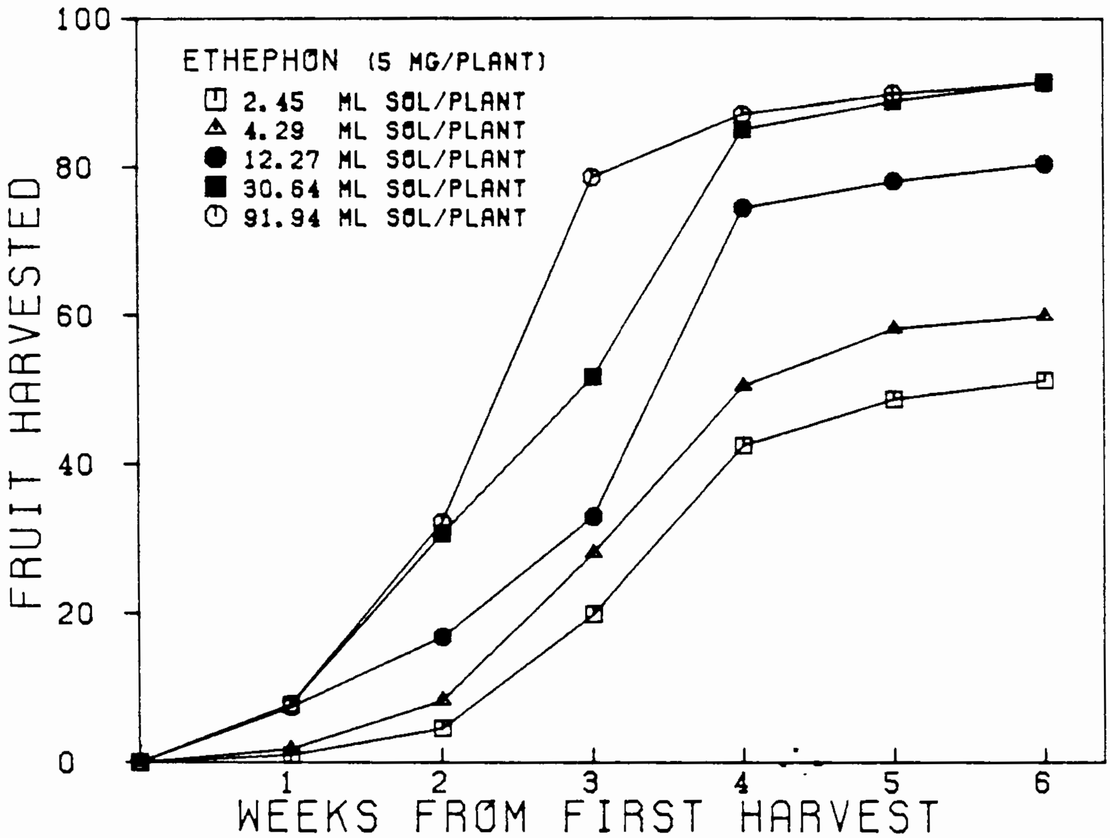

Figure 9. Cumulative Number of Ripe Fruit Harvested After Forcing with Different Rates of Ethephon Carrier. Data are the means for for four Replications.

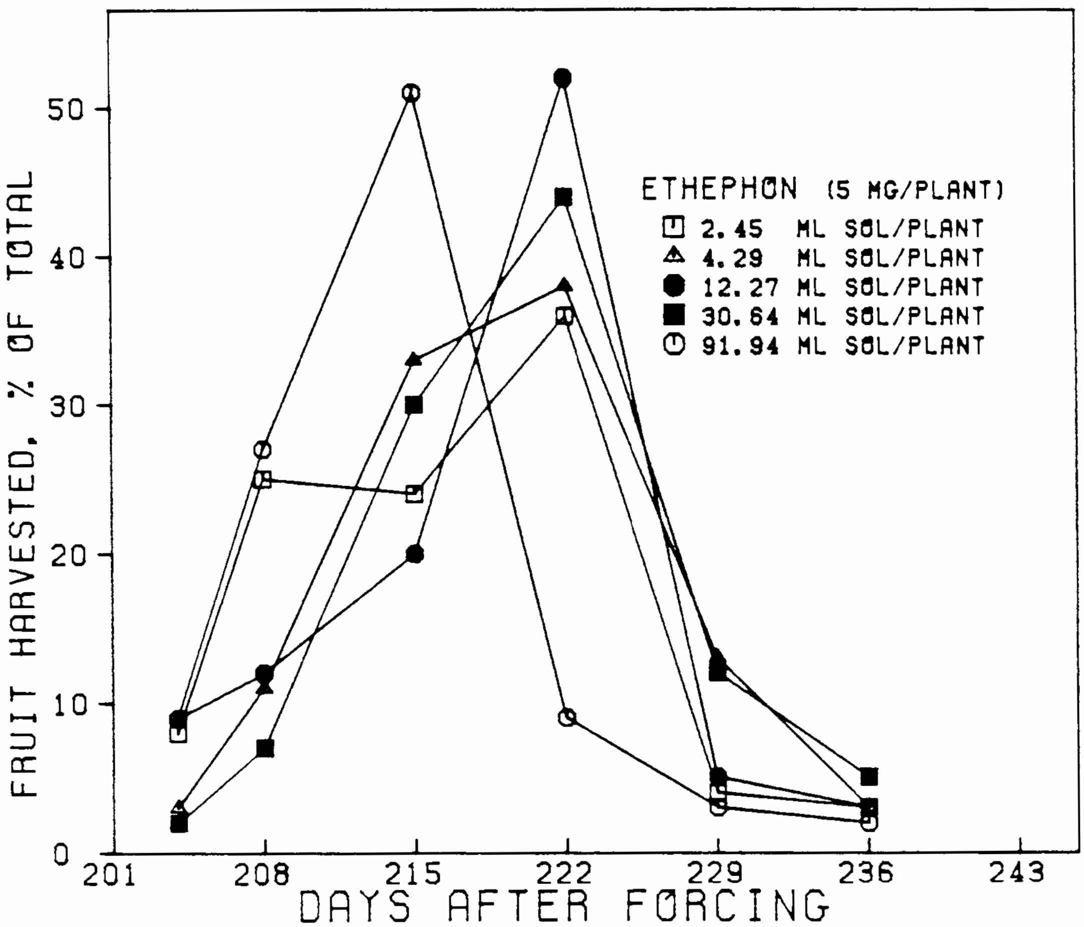

Figure 10. Plant Crop Harvest Curves for 'Smooth Cayenne' Pineapple Forced with Different Rates of Ethephon Carrier.

Table 4

Effects of Ethephon Carrier Rate When Used As A Flower Inductant on Fruit Characteristics of 'Smooth Cayenne' Pineapple

		FRUIT									
Carrier Rate[+++]	Forcing to Harvest	Weight	Length	Top Diameter	Bottom Diameter	Cannery Size	Fruitlets Per Long Spiral	Fruit Defect	Total Soluble Solids	Acid As Citric	Crown
-ml/plant-	-days-	-kg-	cm	cm	cm				%	%	-kg-
2.45	219.2a[+]	1.84a	17.12a	10.79ab	12.69a	2.06a	15.12a	1.17a[++]	15.49a	0.95a	0.290ab
4.29	217.6a	1.80a	17.02a	10.66b	12.60ab	2.03a	15.30a	1.24a	15.48a	0.92a	0.277c
12.27	215.2b	1.83a	16.85a	11.08ab	12.34b	2.07a	15.34a	1.16a	15.19ab	0.99a	0.293a
20.64	214.0b	1.81a	17.24a	11.16a	12.49ab	2.04a	15.44a	1.23a	15.39ab	0.94a	0.280bc
91.94	214.1b	1.80a	17.12a	11.05ab	12.51ab	2.04a	15.68a	1.19a	14.98b	0.89a	0.280bc

\+ Means within the same column which are followed by the same letter are not significantly different at 5% level as determined by Duncan's Multiple Range Test.

++ Normal fruits were scored as 1.0 and abnormal fruit (crooked crown, multiple crown, dwarfed, cracked shell, bottle neck, and sunburn) were scored as 2.0.

+++ The solution used contained 4% urea (w/v) and 5 mg ethephon.

Mean harvest date was shortened by two to three days with the two higher volumes of ethephon carrier compared to the lower ones (Table 4).

In this trial, the mean number of days from forcing to harvest was 216, a value higher than that reported by Wee and Ng (1971) or Dass et al. (1975). As was explained in Experiment One, this length of time is normal for plants forced in winter.

As in Experiment One, there was no significant effect of treatment on average fruit weight (Table 4; Appendix Table 9). Also, the overall mean fruit weight of this experiment was 1.81 which is equivalent to the mean fruit weight obtained in Experiment One.

The lack of significant treatment effects on fruit weight in both experiments indicates that ethephon has little effect on average fruit weight of Smooth Cayenne pineapple, a finding confirmed by others. (Norman, 1977; Teisson, 1979).

Fruit length also did not respond to treatment (Appendix Table 9). The highest mean fruit length (17.24 cm) was recorded in fruits coming from plants that received the 30.6 ml ethephon treatment, while the lowest mean fruit length (16.85) was recorded in fruits produced by plants that received the 12.3 ml ethephon treatment (Table 4).

The results of this experiment indicated that ethephon concentration did not influence fruit length.

Fruit top diameter increased significantly with increasing rate of ethephon carrier although differences between treatments were small (Table 4; Appendix Table 9).

The lack of significant differences (Table 4) between the mean fruit top diameters of treatment 1, 3, and 5 (2.45, 12.3 and 91.9 ml ethephon solution per plant) of this experiment compared to the significant difference between treatment means of Experiment One suggests that fruit top diameter is more affected by ethephon rate than by rate of ethephon carrier.

Fruit bottom diameter was not affected significantly by ethephon concentration (Appendix Table 9), thus confirming the observations of Dodson (1968) that the use of growth regulators had no significant effect on fruit bottom diameter.

Fruit cannery size did not respond to treatment and the results reported here (Table 4) agree with those of Experiment One. Most of the fruits produced were size 2 and only a smaller percentage were size 2½. There was an indication that the number of 2½ size fruits decreased as the number of plants per acre increased at least up to 64,220 plants per hectare (26,000 plants per acre). (Pineapple Research Institute of Hawaii, unpublished). This suggests that the small average fruit size reported here resulted from the high planting density used in this trial.

The number of fruitlets per long spiral did not respond to treatment (Appendix Table 9). However, the mean number of fruitlets per long spiral tended to decrease with increasing concentration of ethephon (Table 4).

Only 18% of the fruits showed some signs of fruit abnormality and there was no significant treatment effect (Appendix Table 9). There was also no significant effect of treatment on fruit abnormalities (Table 4).

There were no significant differences in percentage total soluble solids or titratable acids between the treatments (Appendix Table 9). The overall mean fruit acidity was 0.94%, a value essentially identical to that obtained for Experiment One. However, in contrast to the results of Experiment One, there was no significant treatment effect on fruit acidity. This shows that ethephon rate influences fruit acidity more than ethephon carrier rate.

In this trial, crown weight was significantly affected by treatment (Table 4; Appendix Table 9). There were no consistent trends with treatment and differences between treatments were small. There was no obvious explanation for the differences in crown weight.

There was no significant treatment effect on the number of slips and suckers produced per plant (Table 5; Appendix Table 9). However, the average number of slips and suckers produced per plant decreased as the concentration

Table 5

Effects of Ethephon Carrier Rate When Used As A Flower Inductant on Slip and Sucker Production of 'Smooth Cayenne' Pineapple

CARRIER RATE+	SLIPS PER FORCED PLANT	SUCKERS PER FORCED PLANT
-ml/plant-		
2.45	0.70a++	0.98a
4.29	0.81a	1.16a
12.27	0.95a	1.05a
30.64	1.32a	1.08a
91.91	1.59a	1.19a

+ The solution used contained 4% urea (w/v) and 5 mg ethephon.

++ Means within the same column which are followed by the same letter are not significantly different at 5% level as determined by Duncan's Multiple Range Test.

of ethephon increased (Table 5).

Simple Linear Correlations Between Several Fruit Characteristics

In both Experiment One and Experiment Two, a high correlation between fruit weight, fruit length and number of fruitlets (eyes) produced per long spiral was obtained. The data for Experiment Two are presented in Table 6. Fresh fruit weight was positively correlated with fruit bottom diameter and the correlation coefficient was close to that obtained by Biswas et al. (1979). However, there was poor correspondance between fresh fruit weight and crown weight, and the correlation coefficient was essentially lower than that obtained by Biswas et al. (1979).

Table 6

Simple Linear Correlations Between
Several Fruit Characteristics for Fruit from Plants Forced
with Different Rates of Ethephon Carrier

COMPARISON	CORRELATION COEFFICIENT	LEVEL OF SIGNIFICANCE	SAMPLE SIZE (N)
Fruit weight with crown weight	0.0041^{ns}	0.8762	1423
Fruit weight with bottom diameter	0.77^{+}	0.0001	273
Fruit weight with fruit length	0.75^{+}	0.0001	273
Fruit weight with fruitlet number	0.60^{+}	0.0001	273
Fruit length with fruitlet number	0.72^{+}	0.0001	273

+ Highly significant

^{ns} Not significant

V. SUMMARY AND CONCLUSION

Two field experiments were conducted to determine the effects of ethephon rate and rate of ethephon carrier, on forcing percentage, fruit characteristics and slip and sucker production of Smooth Cayenne pineapple grown in Hawaii.

In Experiment One, the rates of ethephon per plant were 0.5, 1.0, 2.5, 5.0, and 10.0 mg applied in conjunction with 4% urea, at a constant rate of 12.3 ml solution per plant. In Experiment Two, 5.0 mg of ethephon was applied in a 4% urea solution at a rate of 2.4, 4.3, 12.3, 30.6 and 91.9 ml solution per plant.

The treatments were applied January 21, 1981 on plants approximately 10 months old. In Hawaii, forcing is relatively easy in December and January because of the relatively cool temperatures and shorter daylengths that prevail. Data were collected on percentage of plants induced to flower, on final yield, and on fruit weight and related characters.

The following conclusions can be drawn from these two experiments.

1. The results reported here agree with the findings of many investigators that ethephon is an effective

flower inducer. Flowering response to ethephon-urea sprays increased with increasing rate per plant and increasing rate of ethephon carrier used. The optimum rate found was 10.0 mg ethephon per plant, and the optimum rate of ethephon carrier was between 30.6 and 91.9 ml. The flower induction percentage increased to a maximum of 94% with 30.6 and 91.9 ml per plant. The lower rates and volumes of ethephon resulted in poor forcing. This would indicate that these levels were too low to properly cover and stimulate (under the conditions of these trials), the biochemical processes that induce flowering in pineapple.

2. None of the rates or volumes used had a significant effect on fresh fruit weight, crown weight, fruit cannery size, number of fruit abnormalities, fruit bottom diameter, fruit length, total soluble solids or number of eyes per long spiral. Fruit titratable acids did decrease slightly with increasing rate of ethephon.

3. The number of slips produced per plant was decreased significantly with increasing rate of ethephon.

4. Fresh fruit weight and fruit length were positively correlated with the number of eyes per long sprial.

Based on the results of this trial, the optimum rate of ethephon and carrier for forcing would be 5 or 10 mg ethephon per plant in 91.9 ml solution per plant. However, additional trials are needed at higher volumes than were used in the ethephon rate test to more adequately investigate the effects of ethephon rate on forcing success. The effects of the addition of sodium carbonate or borax in order to raise the pH and thereby make more ethylene available to the plant over a shorter time period also warrent investigation.

APPENDIX

Table 7

Analysis of Variance Tables for the Effects of
Ethephon Rate when Used As A Flower Inductant
on Fruit Characteristics of 'Smooth Cayenne' Pineapple

SOURCE	DEGREES OF FREEDOM	MEAN SQUARES										
		Forcing to Harvest	Fruit Weight	Length	Diameter		Cannery Size	Fruitlets Per Long Spiral	Fruit Defect	Total Soluble Solids	Acid As Citric	Crown
					Top	Bottom						
		-days-										
Rep	3	4.020	0.003	0.160	0.071	0.072	0.000[a]	0.513	0.056	0.183	0.004	0.001
Treat	4	87.673^{++}	0.032	1.143	0.489^{++}	0.057	0.008	0.450	0.049	0.260	0.013^{+}	0.000[a]
Error	12	9.875	0.0118	0.068	0.046	0.119	0.003	0.708	0.022	0.179	0.004	0.000[a]
Total	19	25.329	0.0146	0.308	0.143	0.098	0.004	0.623	0.033	0.196	0.006	0.000[a]

+ Denotes significance at $p = 0.05$

++ Denotes significance at $p = 0.01$

[a] Means actual value = 0.0001

Table 8

Analysis of Variance Tables for the Effects of Ethephon Rate When Used As A Flower Inductant on Slip and Sucker Production of 'Smooth Cayenne' Pineapple

SOURCE	DEGREES OF FREEDOM	MEAN SQUARES SLIP	MEAN SQUARES SUCKER
Rep	3	0.160	0.013
Treat	4	1.142^{+}	0.151^{++}
Error	12	0.067	0.136
Total	19	0.308	0.043

\+ Denotes significance at p = 0.05

++ Denotes significance at p = 0.01

Table 9

Analysis of Variance Tables for the Effects of Ethephon Carrier Rate When Used As A Flower Inductant on Fruit Characteristics of 'Smooth Cayenne' Pineapple

SOURCE	DEGREES OF FREEDOM	MEAN SQUARES										
		Forcing to Harvest	Fruit Weight	Length	Diameter		Cannery Size	Fruitlets Per Long Spiral	Fruit Defect	Total Soluble Solids	Acid As Citric	Crown
					Top	Bottom						
		-days-										
Rep	3	4.180	0.003	0.834	0.026	0.015	0.004	0.243	0.002	0.166	0.006	0.001++
Treat	4	20.712++	0.001	0.153	0.080++	0.062	0.002	0.180	0.003	0.201	0.004	0.000[b]+
Error	11+++	1.637	0.002	0.290	0.014	0.031	0.001	0.380	0.003	0.063	0.004	0.000[a]
Total	18+++	6.329	0.000[a]	0.360	0.031	0.038	0.001	0.314	0.003	0.113	0.005	0.000[c]

+ Denotes significance at $p = 0.05$

++ Denotes significance at $p = 0.01$

+++ One degree of freedom is lost because of the missing plot

[a] Means actual value = 0.0001

[b] Means actual value = 0.0002

[c] Means actual value = 0.0003

Table 10

Analysis of Variance Tables for the Effects of Ethephon Carrier Rate When Used As A Flower Inductant on Slip and Sucker Production of 'Smooth Cayenne' Pineapple

SOURCE	DEGREES OF FREEDOM	MEAN SQUARES	
		SLIP	SUCKER
Rep	3	0.177	0.068
Treat	4	0.554^{ns}	0.032^{ns}
Error	11^{+}	0.278	0.034
Total	18^{+}		

+ One degree of freedom is lost because of the missing plot

^{ns} Denotes non significance at $p = 0.05$

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